COMPUTATIONAL FLUID DYNAMICS STUDY OF AIR POLLUTANT DISPERSION AROUND KUANTAN

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MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Pencemar udara seperti klorin berbahaya kepada benda hidup, alam sekitar dan struktur bangunan apabila ia terkumpul di udara dalam kepekatan yang cukup tinggi. Pendedahan kepada gas klorin boleh menyebabkan kesan akut atau kronik bergantung kepada kepekatannya. Di malaysia, kawasan perindustrian Gebeng merupakan salah satu kawasan perindustrian terbesar yang terdiri daripada pelbagai kilang pemprosesan seperti petrokimia dan kilang polimer di mana klorin biasanya digunakan dalam petrokimia dan polimer seperti Polyplastics Asia Pacific, Lynas, Petronas-MTBE dan Kaneka Malaysia. Oleh sebab itu, terdapat potensi yang tinggi untuk pembebasan tidak sengaja klorin di kawasan yang dipilih itu dan juga adalah sebab utama dalam memilih klorin sebagai bahan pencemar. Penyebaran pencemar udara dipengaruhi oleh keadaan cuaca dan topografi. Pengukuran dalam bidang eksperimen mempunyai batasan untuk memberikan maklumat terperinci terhadap aliran udara di kawasan kompleks dan oleh itu *computational fluid dynamics* (CFD) digunakan untuk memberikan maklumat yang komprehensif mengenai pengangkutan spesies dan pergolakan pada masa yang sama. Untuk memastikan ketepatan aliran udara pada model CFD, ia mesti disahkan sebelum ia digunakan secara rutin. Jadi, salah satu objektif kajian ini adalah untuk mengkaji aliran angin melalui model yang berskala kecil dengan menggunakan pengukuran *particle image velocimetry* (PIV) dan membandingkannya dengan simulasi CFD. Untuk mencapai objektif ini, parameter seperti kelajuan angin dan arah dikumpulkan dan akan digunakan untuk mendapatkan keputusan dengan menggunakan CFD sebagai alat simulasi. Angin timur biasa dengan kelajuan angin 1.78 m/s digunakan. Aliran perolakan telah dimodelkan dengan menggunakan model *scale-adaptive simulation* (SAS). Model ini telah disahkan dengan pengukuran PIV pada model topografi skala kecil. Ramalan CFD menunjukkan persetujuan yang baik dengan sisihan antara 1.5 hingga 2.6 % daripada pengukuran PIV itu. Oleh itu, model ini boleh digunakan untuk menilai kesan yang menggabungkan permukaan rupa bumi, arah angin dan kelajuan pada penyebaran pencemaran di sekitar kawasan perindustrian Gebeng. Hasil kajian mendapati bahawa kawasan kediaman R1 (Kampung Baru Gebeng, Tanjung Rhu, Kampung Sungai Ular, Kampung Darat Sungai Ular dan Kampung Baging) dan R2 (Kampung Selamat, Kampung Berahi, Kampung Balok, Kampung Seberang Balok, Kampung Balok Baru dan Kampung Balok Perdana) akan tejejas apabila kebocoran klorin berlaku pada bulan Jun hingga September dan November hingga Jan. Pelepasan yang tidak disengajakan gas klorin ini mungkin telah membawa kepada hal kecemasan. Oleh itu, ia juga penting untuk membangunkan pelan pemindahan keselamatan yang sesuai sekiranya berlaku kemalangan kebocoran klorin. Laluan dan pusat pemindahan keselamatan yang sesuai adalah dicadangkan untuk kes apabila kawasan perumahan R1 dan R2 terjejas.

ABSTRACT

Air pollutant like the chlorine is harmful to living things, environment and building structures when it accumulates in the air in sufficiently high concentration. Exposure to chlorine gas can cause acute or chronic effects depending on its concentration. In Malaysia, Gebeng industrial area is one of the largest industrial area that consists of various processing plant such as petrochemical and polymer plant where the chlorine is commonly used in the petrochemical and polymer plants such as Polyplastics Asia Pacific, Lynas, Petronas-MTBE and Kaneka Malaysia. So, there are high potential to accidental release of chlorine in the selected area thus as the main reason on choosing the chlorine as pollutant. Air pollutant dispersion is significantly affected by the meteorological and topographical conditions. The field experiment measurement has the limitations to provide detail information of air flow on complex terrain and hence computational fluid dynamics (CFD) techniques is applied to provide the comprehensive information on the species transport and turbulence simultaneously. To ensure the accuracy of the air flow on CFD model, it must be validated before it routinely used. So, one of the objectives for this study is to model the wind flows past a scaled-down model using particle image velocimetry (PIV) measurement and compare with the CFD simulation. To achieve this objective, parameter such as wind speeds and directions was collected and will be used to obtain the results by using CFD as a simulation tools. The typical eastern wind with wind speed 1.78 m/s is used. The turbulence flow was modelled using scale-adaptive simulation (SAS) turbulence model. The model was validated with the PIV measurement on the scale down topography model. The CFD prediction showed good agreement with the error ranging 1.5 to 2.6% from the PIV measurement. Hence, the model can be used to evaluate the combine effect of surface terrain, wind direction and speed on the pollution dispersion around Gebeng industrial area. It was found that the residential area R1 (Kampung Baru Gebeng, Tanjung Rhu, Kampung Sungai Ular, Kampung Darat Sungai Ular and Kampung Baging) and R2 (Kampung Selamat, Kampung Berahi, Kampung Balok, Kampung Seberang Balok Kampung Balok Baru and Kampung Balok Perdana) are affected when the chlorine leakage occurs during June to September and November to January, respectively. Accidental release of this chlorine gas may have led to the emergencies. Hence, it is also important to develop a suitable safety evacuation plan in the event accidental chlorine leak. Suitable safety evacuation route and points is proposed for the case when the residential area R1 and R2 are affected.

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LIST OF SYMBOLS

α	Speed of sound (m/s)
C_μ	Coefficient of turbulent viscosity
$C_{1\epsilon}$	Constant of production rate
$C_{2\epsilon}$	Constant of destruction rate
$C_{3\epsilon}$	Coefficient of production rate
D_m	Diffusion coefficient (m^2/s)
D_t	Turbulent diffusion coefficient (m^2/s)
G_k	Production term of turbulence kinetic energy
G_b	Production term due to turbulence buoyancy
g_i	Gravitational vector
$\vec{J}$	Diffusion flux
k	Turbulent kinetic energy (m^2/s^2)
L	Length scale in SAS model
L_{vK}	Von Karman length scale
M_t	Turbulent Mach number
P_k	Production rate term in SAS model
Pr_t	Turbulent Prandtl number
R	Source term by chemical reaction
S	Mean strain rate
S_i	Additional term
T	Temperature (K)
$\vec{u}$	Velocity (m/s)
Y	Mass fraction
Y_M	Dilatation dissipation term
β	Thermal expansion coefficient
μ_t	Turbulent viscosity (kg/m.s)
ρ	Density (kg/m^3)
μ	Viscosity of fluid (kg/m.s)
σ_ϵ	Turbulent Prandtl number for turbulent dissipation rate
σ_k	Turbulent Prandtl-Schmidt number for turbulent kinetic energy
σ_Φ	Turbulent Prandtl number for SAS model

ε	Turbulent dissipation rate (m^2/s^3)
Φ	Coefficient
γ	Ratio of specific heat
$\zeta_1, \zeta_2, \zeta_3$	Constant

LIST OF ABBREVIATIONS

AABL	Adiabatic atmospheric boundary layer
ABS	Acrylonitrile butadiene styrene
AP	Aspiration probe
CCD	Charged-couple device
CFD	Computational fluid dynamics
FFID	Fast flame ionisation detector
GIE	Gebeng Industrial Estate
IBM	Immersed Boundary Method
LDA	Laser Doppler anemometry
LDV	Laser Doppler velocimetry
LES	Large eddy simulation
LS-PIV	Large scale-particle image velocimetry
LST	Light scattering technique
MADM	Module for the atmospheric dispersion modelling
MIC	Methyl isocyanate
MIDA	Malaysian Investment Development Authority
MSL	Mean sea level
MTBE	Methyl tert-butyl ethylene
PIV	Particle image velocimetry
PPM	Parts per million
PTV	Particle tracking velocimetry
RANS	Reynolds-averaged Navier-Stokes
RKE	Realizable k-ε
RNG	Renormalized k-ε
RSM	Reynolds stress model
SAS	Scale adaptive simulation
SKE	Standard k-ε
TIN	Triangulated irregular network
URANS	Unsteady Reynolds-averaged Navier-Stokes

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